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SEI Research Review
Value-Driven Iterative and Incremental Development

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Value-Driven Incremental Development

The current approach in highly-regulated domains, such as DoD, **still** depends on lengthy requirements, design, test, and evaluation cycles

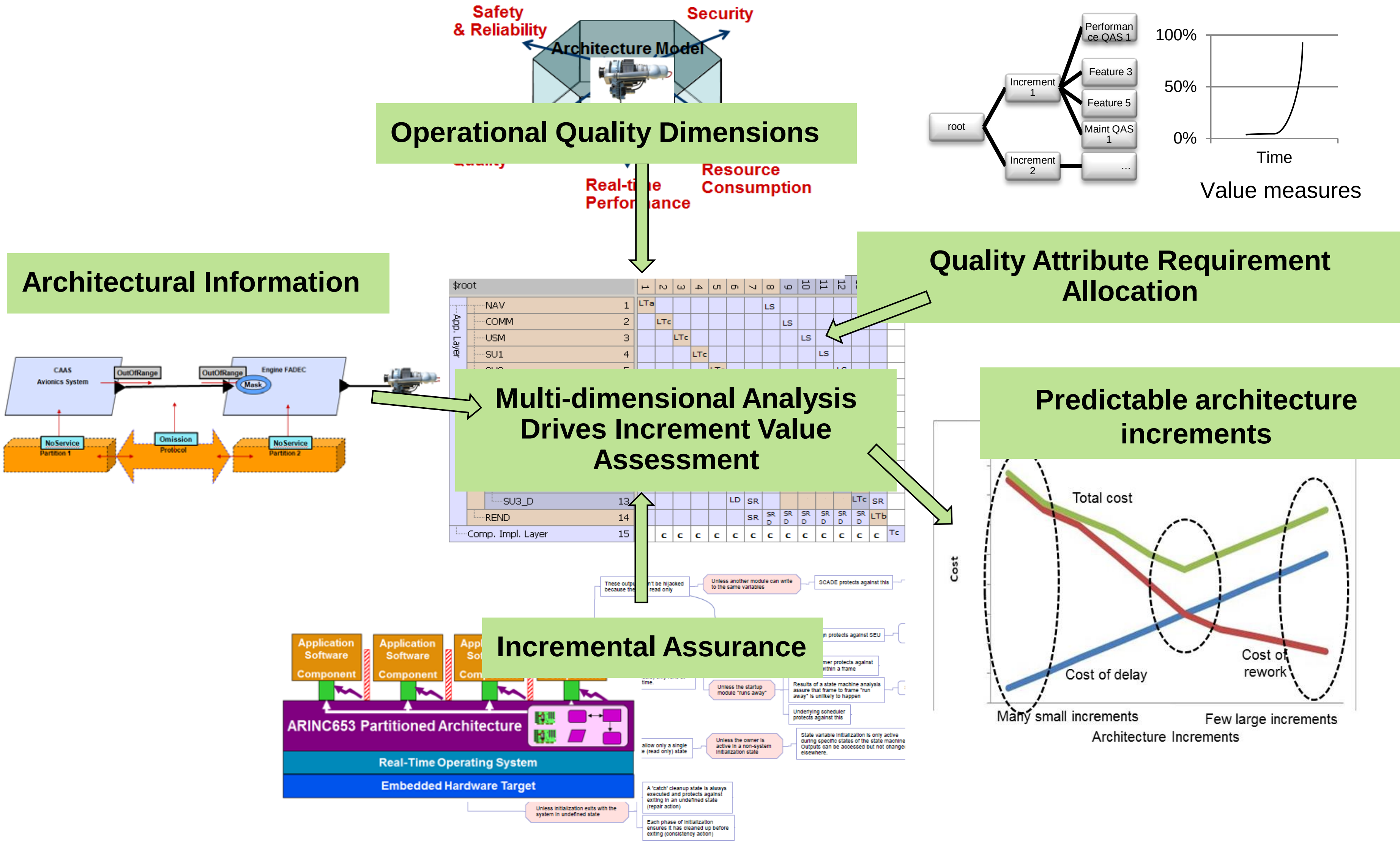
- Excessive documentation without analysis
- Monolithic architecting, modeling, or assurance activities result in rework

The goal of this project is to develop architecture dependency analysis focused techniques to integrate architecture analysis with development efforts early-on and continuously:

Our approach includes:

- Architecture dependency management
- Incremental assurance structuring
- Quality attribute allocation techniques

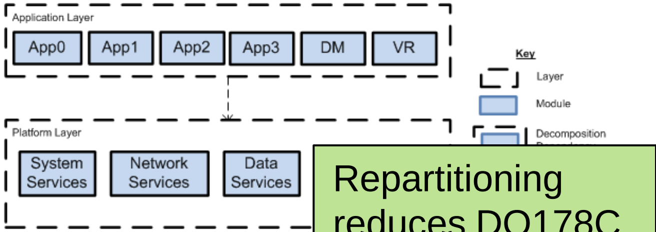
Technical Approach



Architectural Dependencies

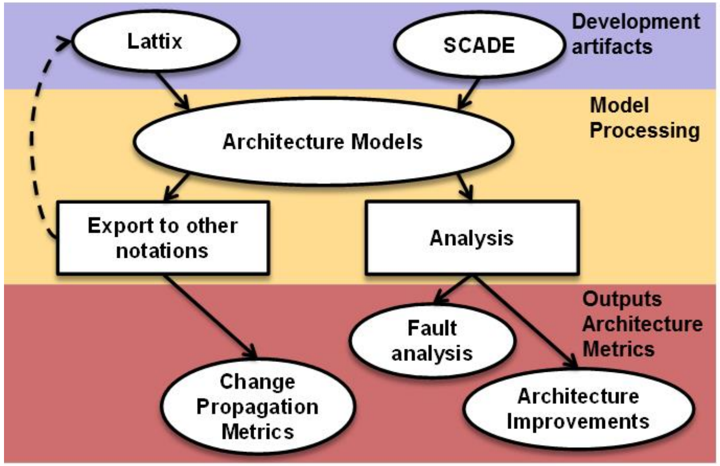
Technical approach

- Track additional information (e.g., safety critical testing level) using a DSM
- Extract fault ontology and propagation-related information from architecture analysis tools (e.g., AADL)
- Apply structural metrics (e.g., stability) on the augmented DSM and check on collaborator data

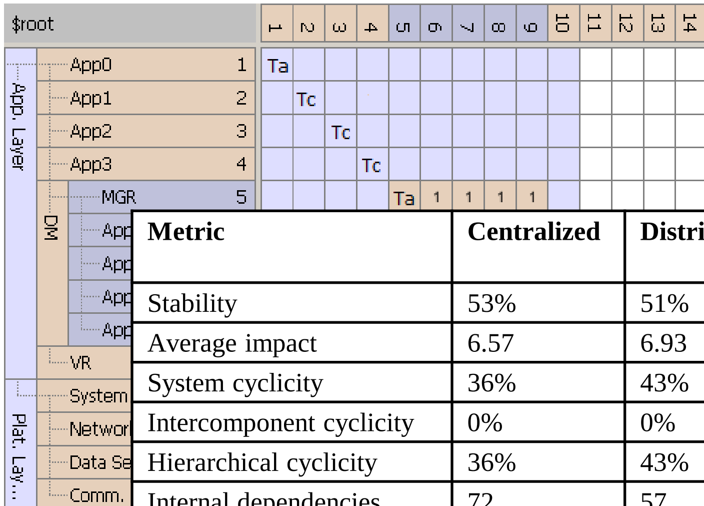


Repartitioning reduces DO178C compliant testing

$root			1	2	3	4	5	6	7	8						
App. Layer	App0	1	Ta													
App. Layer	App1	2		Tc												
App. Layer	App2	3			Tc											
App. Layer	App3	4				Tc										
DM	MGR	5					Ta	1	1	1	1					
DM	App0_DM	6	1				1	Ta	1	1	1					
DM	App1_DM	7		1			1	1	Ta	1	1					
DM	App2_DM	8			1		1	1	1	Ta	1					
DM	App3_DM	9				1	1	1	1	1	Ta					
App. Layer	VR	10					1	1	1	1	1	Tc				
Plat. Lay...	System Services	11	1	1	1	1	1	1	1	1	1	1	Tc	1	1	1
Plat. Lay...	Network Services	12	1	1	1	1	1	1	1	1	1	1		Tc		
Plat. Lay...	Data Services	13	1	1	1	1	1	1	1	1	1	1			Tc	
Plat. Lay...	Comm. Services	14	1	1	1	1	1	1	1	1	1	1				Tc



Architectural Dependencies



Metric	Centralized	Distributed	Health *
Stability	53%	51%	–
Average impact	6.57	6.93	–
System cyclicity	36%	43%	–
Intercomponent cyclicity	0%	0%	=
Hierarchical cyclicity	36%	43%	–
Internal dependencies	72	57	+
Average dependency	5.14	4.07	+
Average cumulative dependency	7.57	7.93	–
Normalized cumulative dependency	2.356	2.467	–
Connectedness	51%	53%	–
Connectedness enrichment	1.00	1.37	–
Connectedness strength	5.86	5.10	+
Coupling	11%	16%	–
Coupling enrichment	1.00	15.00	–
Coupling strength	0.36	0.30	+

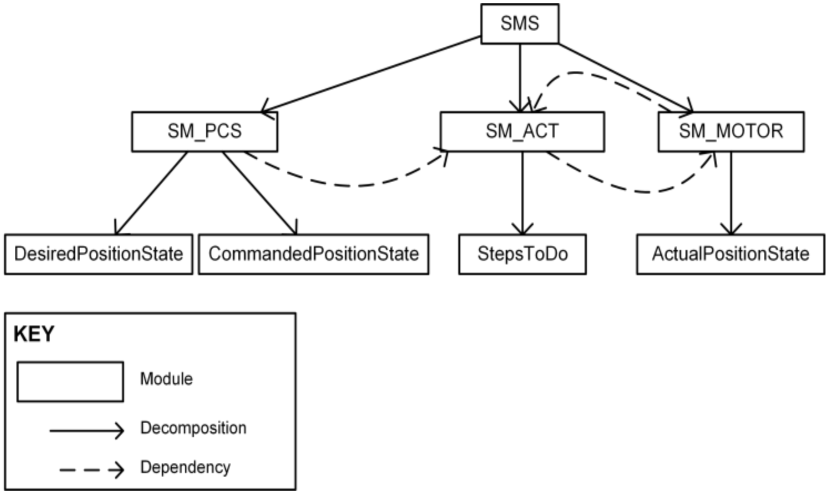
	1	2	3	4	5	6	7	8	9	10
App3_DM (1)		OK			OK					OK
VR (2)	OK			OK				OK	KO	OK
App0 (3)									OK	
App2_DM (4)		OK					OK			OK
App3 (5)	OK									
App1 (6)								OK		
App2 (7)				OK						
App1_DM (8)		OK				OK				OK
App0_DM (9)		KO	OK							KO
MGR (10)	OK	OK		OK				OK	KO	

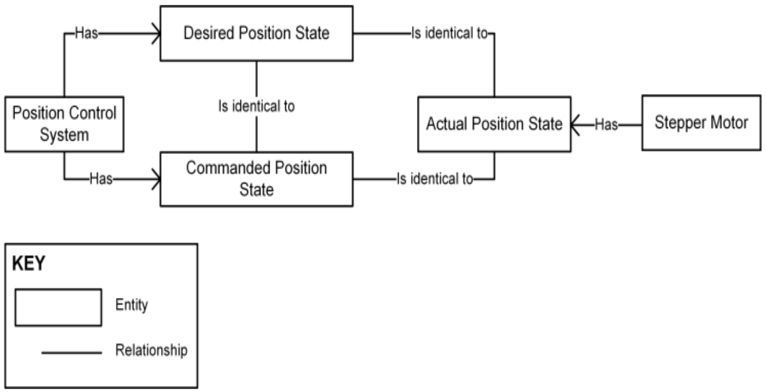
Criticality-level interaction across partitions cannot be captured with code-based analysis

Changes propagate beyond models and implementation

Stepper Motor Example

A stepper motor systems is an open loop system with no feedback on the successful execution of the steps it must take for a position change command.





- How can we ensure that steps are not missed during execution?
- How can we ensure that when change are made testing resources are spent on target?

Dependency Type Guide

Dependency type		Description
A	Aggregation	Data element A and Data element B have a semantic coherence that can be aggregated as Module AB
C	Control	Module A depends on the presence of a correct functioning module B.
D	Data	For a module B to execute correctly, the syntax (type or format)/semantics of the data produced by module A must be consistent with the assumptions of module B.
L	Location	For B to execute correctly, the runtime location of A must be consistent with the assumptions of B.
R	Allocation of responsibilities	Behavior and functionality assigned to design time elements, used to separate concerns, e.g. safety criticality.
S	Sequence of flow	For B to execute correctly, it must receive the data produced by A in a fixed sequence (data flow). For B to execute correctly, A must have executed previously within certain timing constraints (control flow).
P	Physical resource behavior	For B to execute correctly, the resource behavior of A must be consistent with B's assumptions about physical resource (such as bandwidth, memory, storage capacity, CPU, etc.) usage or ownership,
Q	Quality of service	For B to execute correctly, some property involving the quality of the data or service provided by A must be consistent with B's assumptions.
V	Virtual resource behavior	For B to execute correctly, the resource behavior of A must be consistent with B's assumptions about virtual resource usage or ownership

Missing information

Module-view dependencies

	SMS-Arch-1	SMS-Arch-2	SMS-Arch-3	SMS-Arch-4	SMS-Arch-5	SMS-Arch-6	SMS-Arch-7	SMS-Arch-8
SMS-Arch-1: SMS.SM_PCS	.			CD				
SMS-Arch-2: SMS.SM_PCS.DesiredPositionState	D	.						
SMS-Arch-3: SMS.SM_PCS.CommandedPositionState	D		.					
SMS-Arch-4: SMS.SM_ACT				.		CD		
SMS-Arch-5: SMS.SM_ACT.StepsToDo				D	.			
SMS-Arch-6: SMS.SM_MOTOR						.		
SMS-Arch-7: SMS.SM_MOTOR.ActualPositionState						D	.	
SMS-Arch-8: SMS.SM_HM								.

Data and control relationships can be captured

Multi-view dependencies

	SMS-Arch-1	SMS-Arch-2	SMS-Arch-3	SMS-Arch-4	SMS-Arch-5	SMS-Arch-6	SMS-Arch-7	SMS-Arch-8
SMS-Arch-1: SMS.SM_PCS	.			CDS				L
SMS-Arch-2: SMS.SM_PCS.DesiredPositionState	D	.	A				A	
SMS-Arch-3: SMS.SM_PCS.CommandedPositionState	D	A	.				A	
SMS-Arch-4: SMS.SM_ACT	S			.		CD		
SMS-Arch-5: SMS.SM_ACT.StepsToDo				D	.			
SMS-Arch-6: SMS.SM_MOTOR				S		.		
SMS-Arch-7: SMS.SM_MOTOR.ActualPositionState		A	A			D	.	
SMS-Arch-8: SMS.SM_HM	LP							.

Aggregation, sequence of flow, location and physical resource dependencies can be captured when model-based analysis is conducted

Implication on testing resources

Using clustering algorithms we can locate the most connected areas that need to be tested further.

	SMS-Arch-8	SMS-Arch-6	SMS-Arch-4	SMS-Arch-1	SMS-Arch-5	SMS-Arch-2	SMS-Arch-7	SMS-Arch-3
SMS-Arch-8: SMS.SM_HM	.							
SMS-Arch-6: SMS.SM_MOTOR		.						
SMS-Arch-4: SMS.SM_ACT		CD	.					
SMS-Arch-1: SMS.SM_PCS			CD	.				
SMS-Arch-5: SMS.SM_ACT.StepsToDo			D		.			
SMS-Arch-2: SMS.SM_PCS.DesiredPositionState				D		.		
SMS-Arch-7: SMS.SM_MOTOR.ActualPositionState		D					.	
SMS-Arch-3: SMS.SM_PCS.CommandedPositionState				D				.

	SMS-Arch-6	SMS-Arch-8	SMS-Arch-4	SMS-Arch-1	SMS-Arch-5	SMS-Arch-7	SMS-Arch-3	SMS-Arch-2
SMS-Arch-6: SMS.SM_MOTOR	.		S					
SMS-Arch-8: SMS.SM_HM		.		LP				
SMS-Arch-4: SMS.SM_ACT	CD		.	S				
SMS-Arch-1: SMS.SM_PCS		L	CDS	.				
SMS-Arch-5: SMS.SM_ACT.StepsToDo			D		.			
SMS-Arch-7: SMS.SM_MOTOR.ActualPositionState	D					.	A	A
SMS-Arch-3: SMS.SM_PCS.CommandedPositionState				D		A	.	A
SMS-Arch-2: SMS.SM_PCS.DesiredPositionState				D		A	A	.

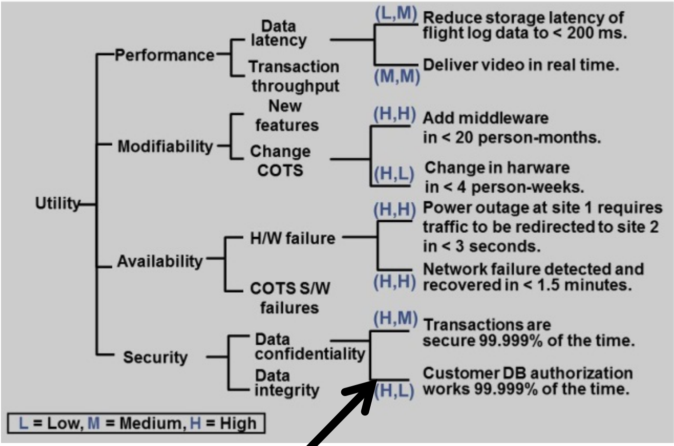
Incremental assurance

Technical approach

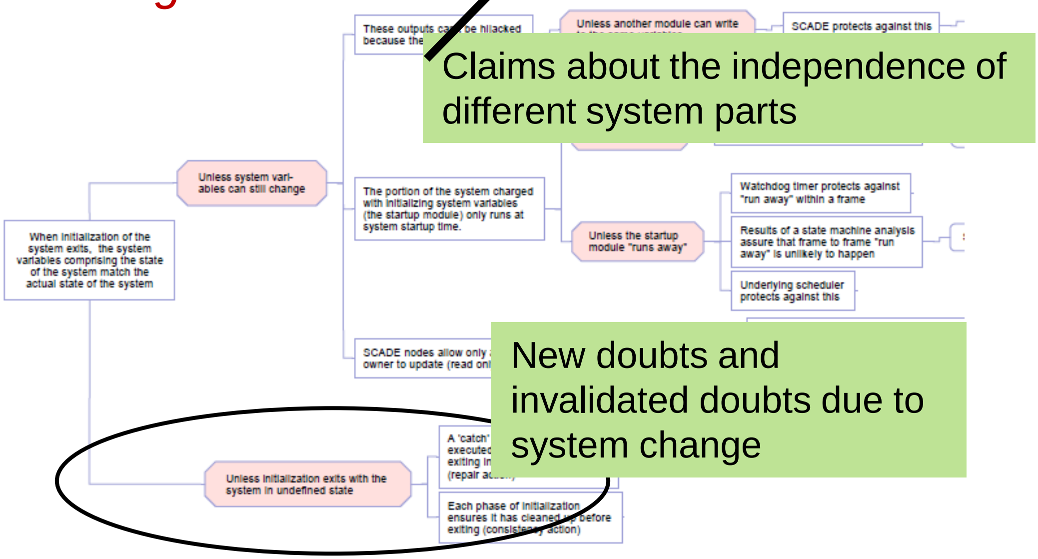
- Use quality attribute utility trees and architectural dependency analysis to structure the system’s architecture and its assurance argument

FY14 results

- confidence map notation and theory
- generation capability of assurance cases from requirements



generate the assurance case



Quality Attribute Allocation to Iterations

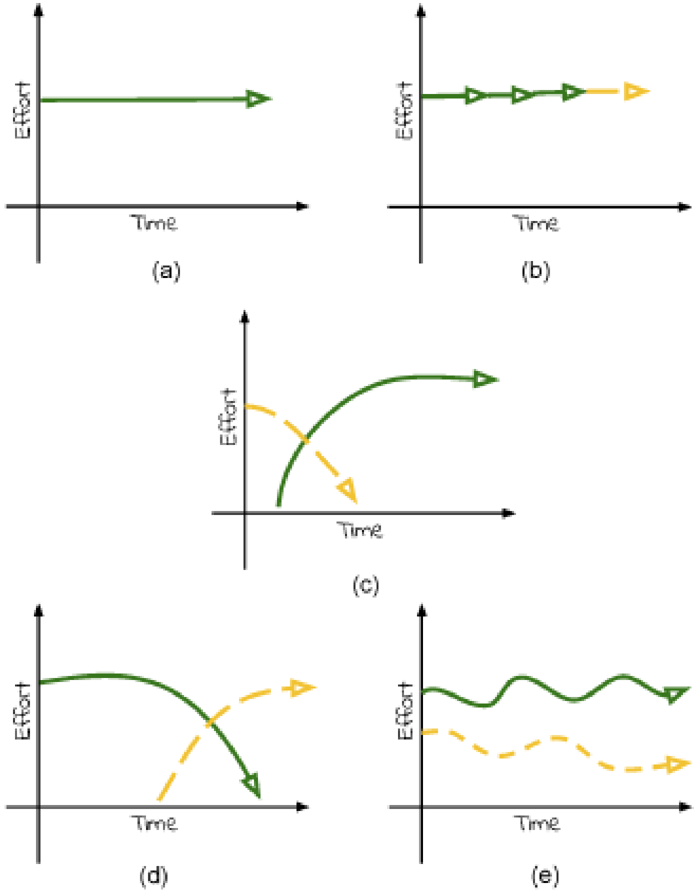
Technical approach

- Use architecture tactics-based and story slicing techniques to link architectural tasks to backlog management tools

FY14 results

- Patterns of iterative incremental development
- Rework occurs regardless of process followed

Ongoing organization wide-surveys of the patterns of iterative incremental development



Example: Performance Improvement Evolution

	QAR Parsing		Value	Effort
A-S1	Stimulus: Context: Response:	Customer initiates manual process (multi-user) Users processing transactions with system Process volume of transactions		
A-S2	Stimulus: Context: Response:	Customer initiates automated process System processing transactions (single-user) Process batch transactions; new time less than current time	Enhanced "Autopilot" feature	3x
A-S3	Stimulus: Context: Response:	Order process initiates transaction System processing transaction; single-user Process individual transaction; new time less than current time	Improved order	1x
A-S4	Stimulus: Context: Response:	Order process initiates transaction System processing transaction; single-user Process individual transaction; processing time less than or equal to 1 s	Further improved order capability	2x
A-S5	Stimulus: Context: Response:	Customer submits orders System processing trans; rotary algorithm; multi-user Process and prioritize transactions	n feature	

Ratcheting Stimulus

Ratcheting Response Measure

Ratcheting Environment

Publications

Prototypes:

Semantic wiki to capture architecture-tactics

Assurance case generation tool

Publications:

Architectural dependency analysis to understand rework costs for safety-critical systems – ICSE 2014

Design Rule Spaces: A New Form of Architecture Insight – ICSE 2014

Evolutionary Improvements of Cross-cutting Concerns: Performance in Practice – ICSME 2014

Increasing Confidence by Strengthening an Inference in a Single Argument Leg: An Alternative to Multi-Legged Arguments – Dependable System Networks (DSN)

Using AI to model quality attribute tradeoffs – AI in Requirements Engineering @ RE 2014

Agile in Distress: Architecture to the Rescue - Principles of Large-Scale Agile Development @ XP Conference

Research Workshops Led:

6th International Workshop on Managing Technical Debt @ ICSME 2014

1st International Workshop on Software Architecture & Metrics @ WICSA 2014

Going Forward in FY15

Improving Software Sustainability through Data-driven Technical Debt Management

What code and design indicators can be discovered in a repeatable way to measure and manage technical debt?

Incremental Life Cycle Assurance of Critical Systems

How can system assurance confidence and cost be improved through requirements coverage and consistency checking and compositional verification evidence?

Team: Value-Driven Incremental Development

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